Site Characterization for CO_2 Storage from Coal-fired Power Facilities in the Black Warrior Basin of Alabama

DE-FE0001910

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University of Alabama

Presented to National Energy Technology Laboratory
2/3/10

Outline

- Goals and Objectives
- Performance Period, Budget
- Project Team
  - Roles and responsibilities
  - Project organization
  - Facilities and other resources
- Background
  - Workplan
  - SOPO Tasks and Deliverables
- Supportive Technical Details
- Schedule and Milestones
- Project Status
- Summary

Goals and Objectives

- Goals
  - Determine the CO_2 storage capacity of multiple stacked saline formations in the Mississippian-Pennsylvanian section of the Warrior Basin of Alabama
  - Assess the risks associated with geologic carbon storage in these sections of the Black Warrior basin
  - Develop a regional plan for carbon sequestration

Goals and Objectives

- Objectives
  - Shoot 2-D seismic profiles
  - Drill 4000 ft exploratory well at Plant Gorgas
  - Core reservoirs and seals
  - Quantify the target reservoir properties using
    - Advanced petrophysical and geophysical techniques
    - Inject/well testing
    - Zone integrity testing using mini-fracs both in the reservoir and seals
  - Laboratory analysis of mineralization
  - Reservoir simulation
  - Develop a best practices manual
  - Leave infrastructure at the plant

Performance Period and Budget

- Performance Period
  - December 8, 2009 to December 7, 2012
  - Divided into three equal budget periods
- Budget Summary
  - Total project cost — $6,538,621
  - Government share — $4,849,924
  - Cost Share — $1,688,697 (26%)
    - Cost share breakdown
      - UA, GSA, Rice University, Southern Company — 45%
      - Service providers — 55%

Project Team, Roles/Responsibilities, and Project Organization

- Project Team
  - Lead — University of Alabama
    - Project management
    - Well drilling and completion
    - Reservoir simulation
    - Geophysics
  - Geological characterization and modeling — Geological Survey of Alabama
  - Mineralization — Rice University
    - Laboratory studies
    - Modeling

Project Team, Roles/Responsibilities, and Project Organization

- Lead
  - Peter Clark P.I. Department of Chemical and Biological Engineering
  - Background
    - Well drilling and completions
    - Well stimulation using fracturing and acidizing
    - Rheology
    - Slurry transport
    - Flow in porous media
  - Role/Responsibilities
    - Overall project management
    - Drilling, completion and well testing

Project Team, Roles/Responsibilities, and Project Organization

- Eric Carlson CoP.I. Department of Chemical and Biological Engineering
  - Background
    - Ph.D. Petroleum Engineering
    - Reservoir modeling
    - Reservoir simulation
    - Reservoir simulator development
    - Well testing
    - High performance computing
  - Roles/Responsibilities
    - Develop the reservoir model (in conjunction with GSA)
    - Develop a reservoir simulator for studying both short and long-term effects of CO_2 injection
    - Integrate mineralization models with reservoir models
    - Analyze well test data

Project Team, Roles/Responsibilities, and Project Organization

- Andrew M. Goodliffe
  - Chief or co-chief scientist for 10 large scale geophysical experiments
    - Gravity, magnetics, seafloor mapping, seismic reflection, refraction
    - Lead scientist for approximately 8 large-scale seismic reflection experiments (typically more than one month in duration)
  - Global field experience – ranging from the Arctic in the winter to the Afar Desert in the summer
  - Extensive experience in seismic survey design and seismic reflection data acquisition
  - Extensive experience in the processing and interpretation of seismic reflection data
    - Includes teaching short courses for the Incorporated Research Institutes for Seismology and Exxon-Mobil
  - Shipboard geophysicist for the Ocean Drilling Program in Papua New Guinea
    - Acquisition of vertical seismic profile data and check shot data, creation of synthetic seismic profiles for numerous well
  - Site Survey Panel member for the International Ocean Drilling Program (2010-2013
    - Assessment of geophysical data used to support proposed drill sites around the world (riser and non-riser)

Project Team, Roles/Responsibilities, and Project Organization

- Andrew M. Goodliffe (cont.)
  - Roles/Responsibilities
    - Manage the acquisition of geophysical data
    - Analyze geophysical data
    - Integrate geophysical information into a geologic model of the reservoir

Project Team, Roles/Responsibilities, and Project Organization

- Jack Pashin, Director, Energy Investigations Program

- Responsibilities
  - Regional significance
  - Geophysical characterization
  - Geologic model of the reservoir
  - Capacity estimates
  - Containment analysis

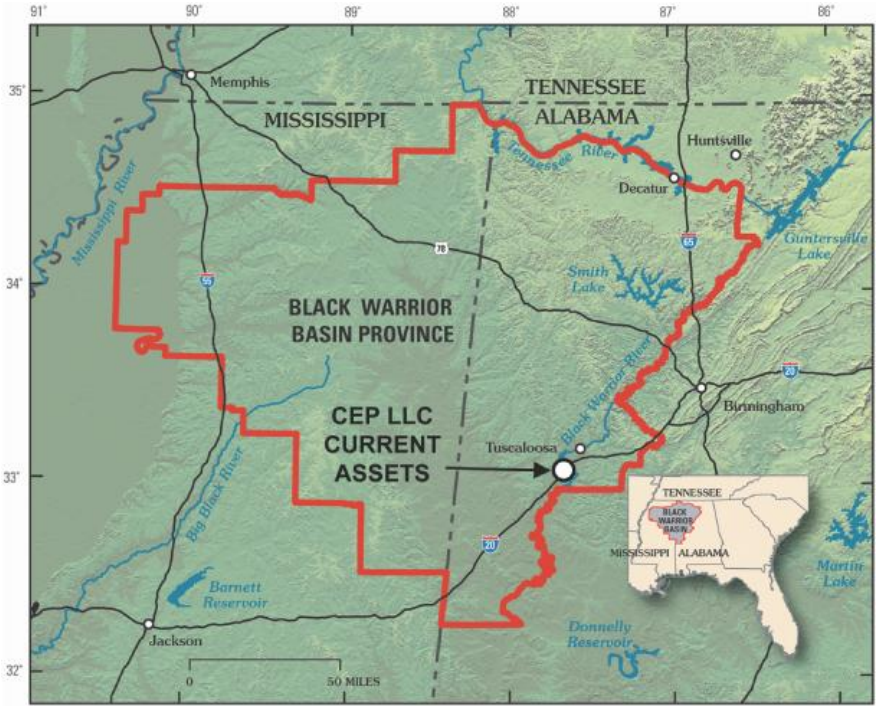
Project Team, Roles/Responsibilities, and Project Organization

- Mason Tomson, Rice University
  - Thirty years of experience in oilfield brine precipitation reactions

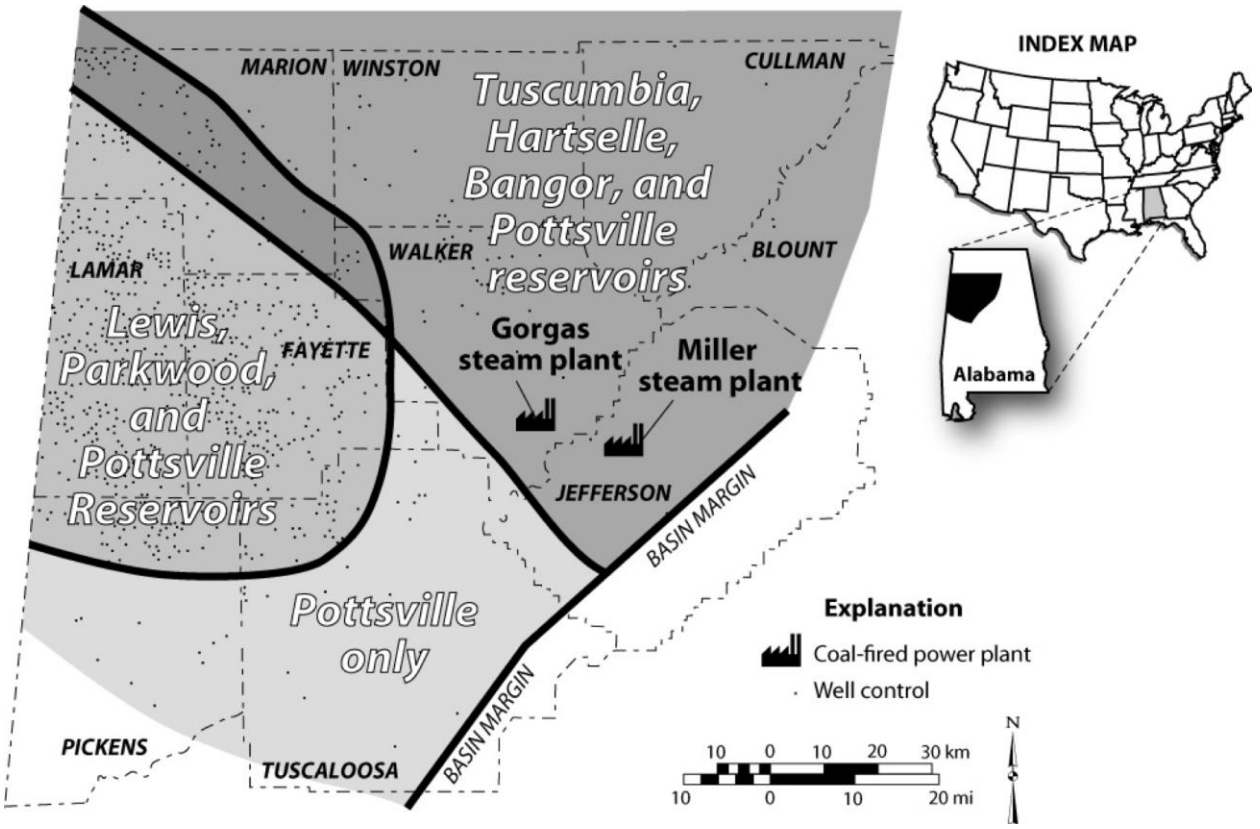
- Roles
  - Short and long-term studies of carbon dioxide interactions with reservoir rocks and fluids
  - Modeling of the interaction of carbon dioxide with reservoir rocks and fluids

Background — Region

- Black Warrior basin of Alabama contains two major coal-fired power plants
  - William C. Gorgas (7.53 Mt)
  - James H. Miller, Jr (19.92 Mt)
- These plants serve the Tuscaloosa — Birmingham corridor
- There are significant potential storage in coal seams in the basin (6 years)

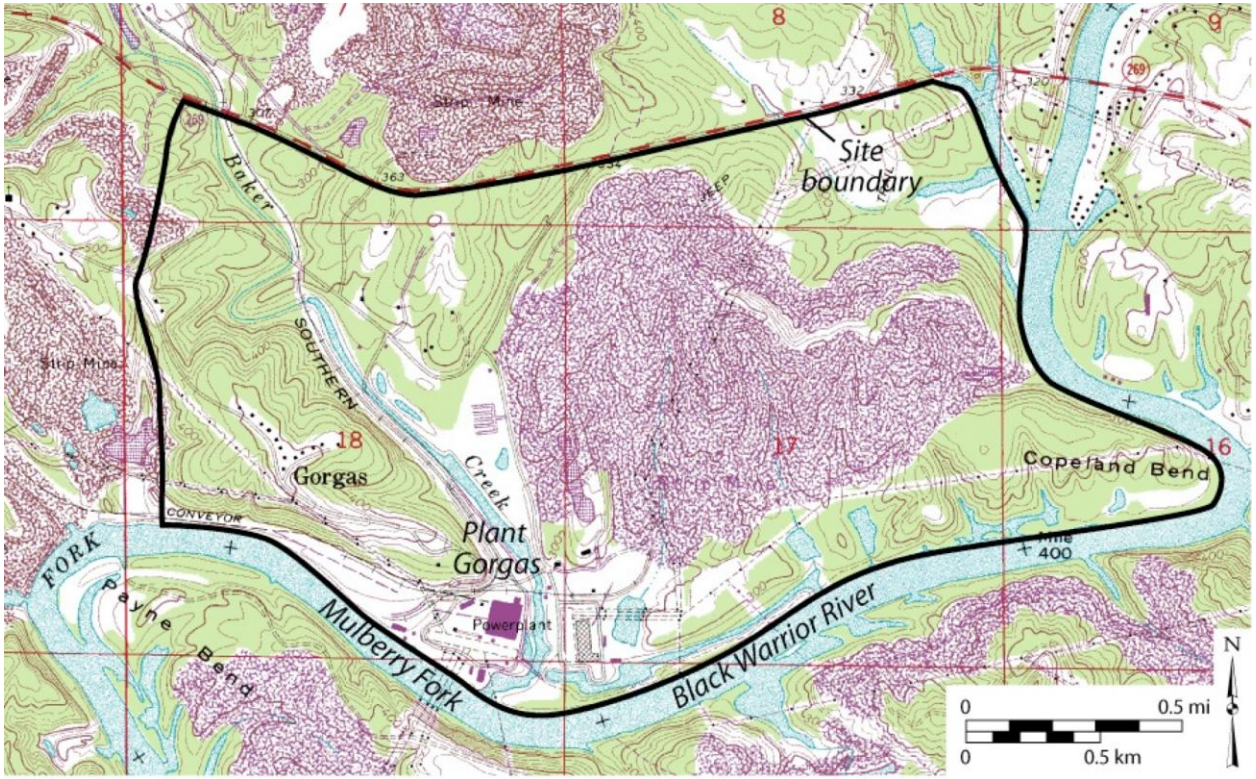


Background — Region



Background — Region

- Gorgas plant property

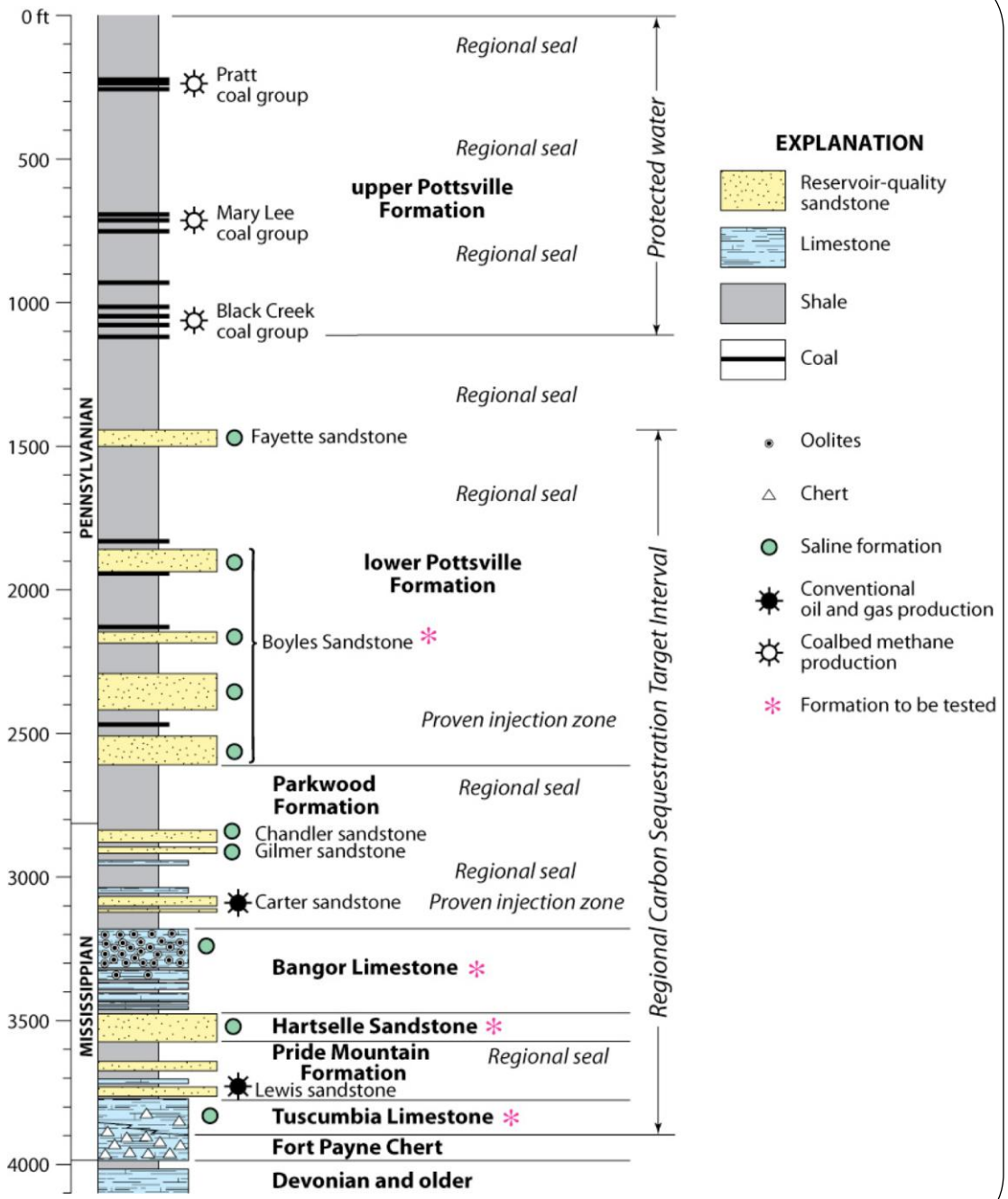


Background — Plant Gorgas

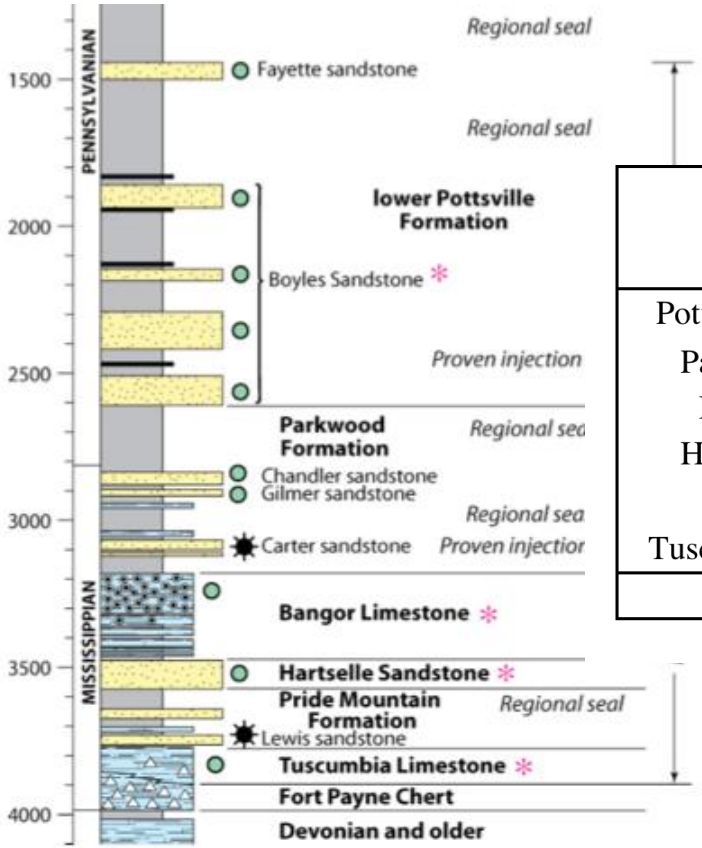
- 1,400 MW plant

Background

- Stacked storage opportunities



Storage Capacity



Formation	Areal extent (mi^2)	Net Pay (ft)	Porosity (%)	Capacity (tonnes/mi^2)	Regional capacity (gigatonnes)
Pottsville Formation**	9,400	260	18	2,031,969	19.1
Parkwood Formation	2,820	48	15	312,611	0.9
Bangor Limestone*	5,640	50	15	325,636	1.8
Hartselle Sandstone*	5,640	72	15	468,916	2.6
Lewis Sandstone	2,820	27	15	175,844	0.5
Tuscumbia Limestone*	5,640	90	15	586,145	3.3
Total				**3,901,121**	**28.2**

* Saline formation present at the site

** Shallower than 2,480 feet at the site.

Characterization

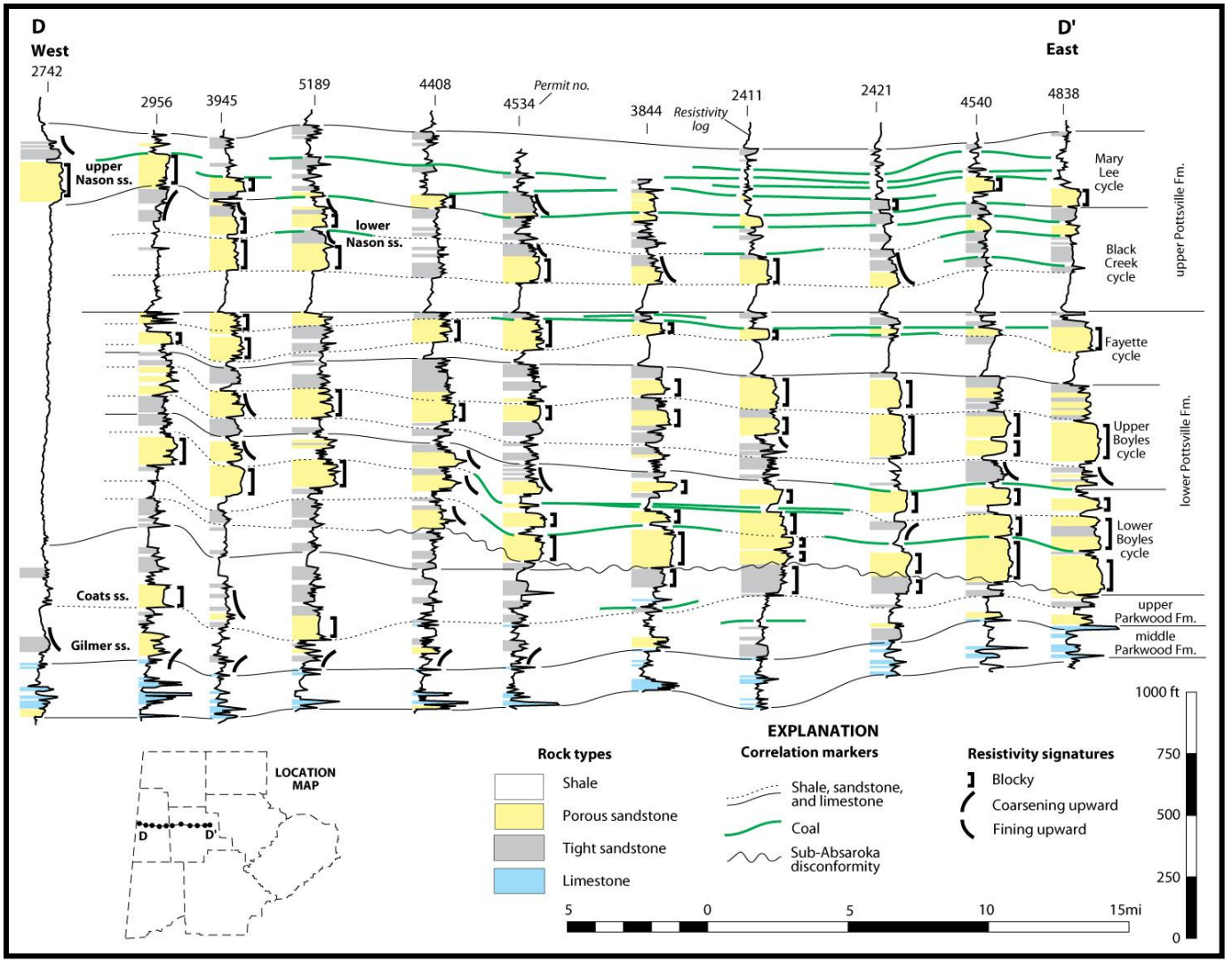
- Geophysical
- Geological
- Reservoir testing
- Reservoir modeling
- Long term storage modeling

Characterization — Overview

- Compile existing data to obtain an initial geologic framework
- The nearest control well is five miles away
- Generate new data using
  - Seismic reflection studies
  - Vertical seismic profiling
  - Borehole gravity
  - Seismic monitoring during injection
  - Well logs
  - Extensive coring of reservoir and seal rock
  - Well testing
  - Geologic modeling
  - Reservoir modeling
  - Long term storage testing and modeling

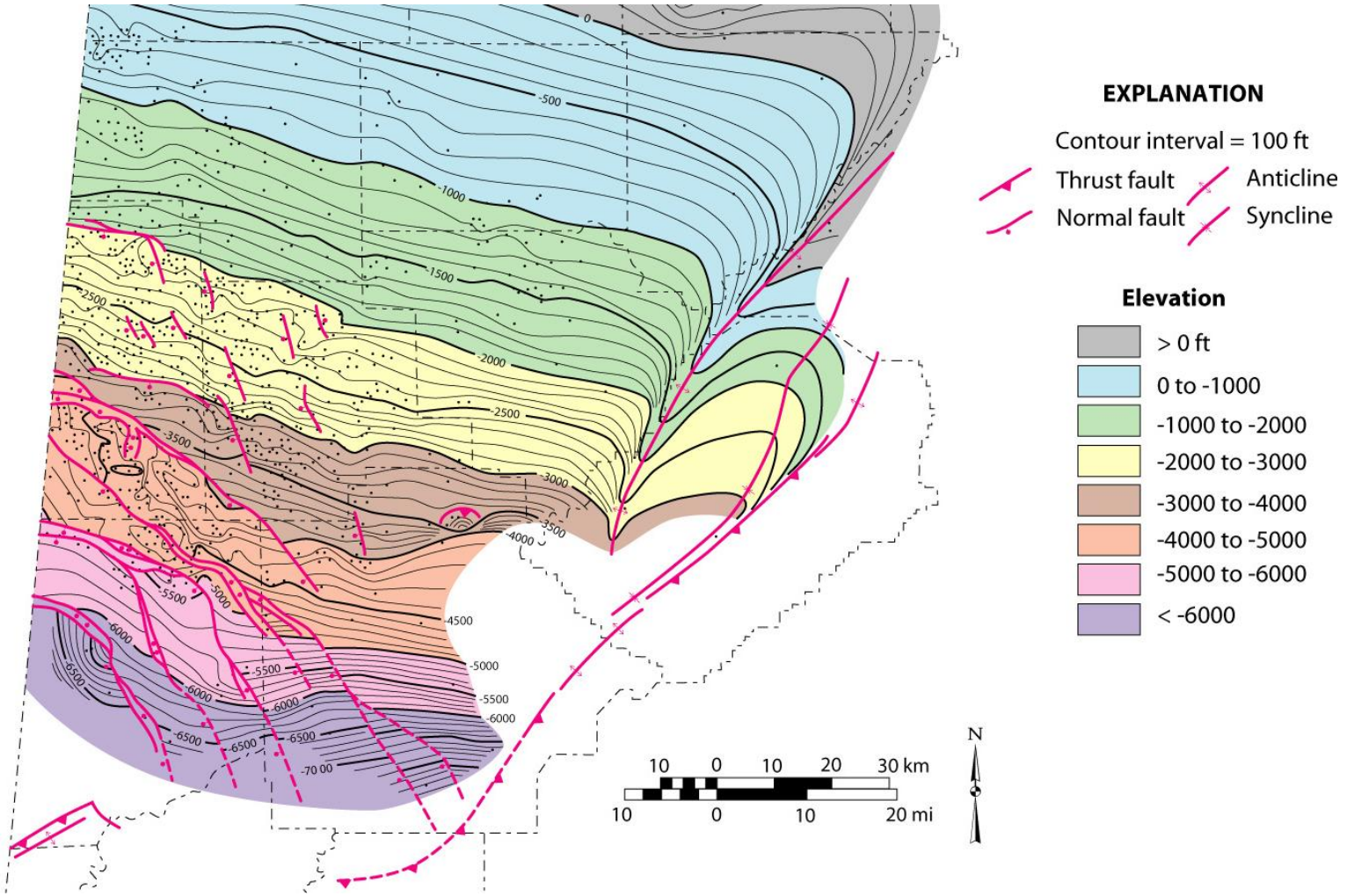
Characterization — Existing Information

- Regional Stratigraphy



Characterization — Existing Information

- Tuscumbia Structure

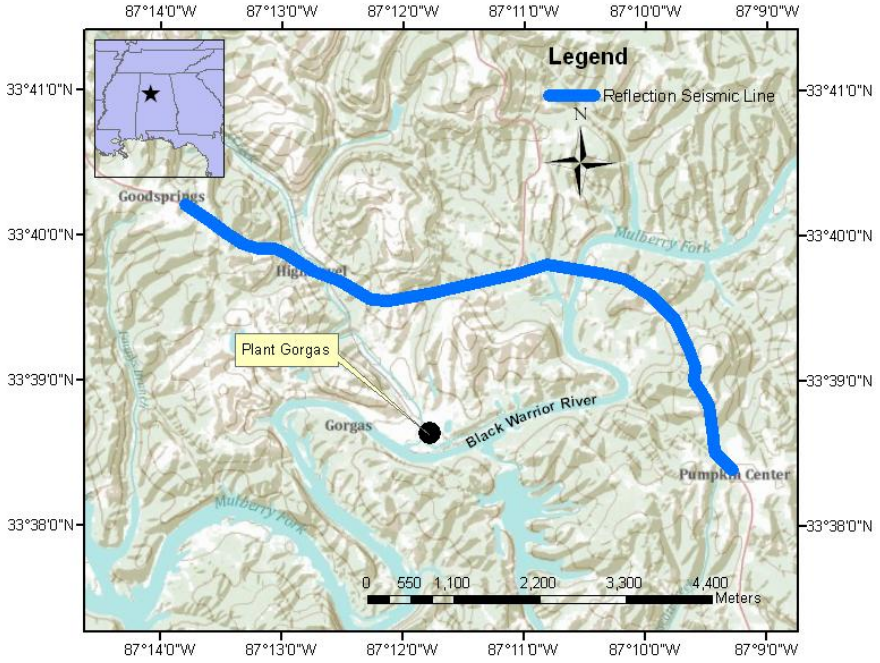


Characterization — Existing Information

- A comprehensive ArcInfo database has been put together for the area in the vicinity of the Gorgas power plant
  - Detailed geological map
  - Well information (down-hole well data is currently being digitized)
  - Geographic information includes land-use, roads, digital elevation models and much more.
- More information will be added to this as the project progress

Characterization — Seismic Studies

- Profile length of 5 miles
  - Collected along route 269
- Receiver interval of 220 foot
- Shot interval of 440 foot
- Radio telemetry used to avoid long lengths of cable
- Maximum offset of 26,400 foot
- Vibroseis and explosive sources under consideration
  - Explosive source would be 1-2.2 pounds of pentolite in a 20 foot hole
- 4-5 days to complete
- Final vendor to be determined
  - In process of discussing details with Boone Exploration Inc.



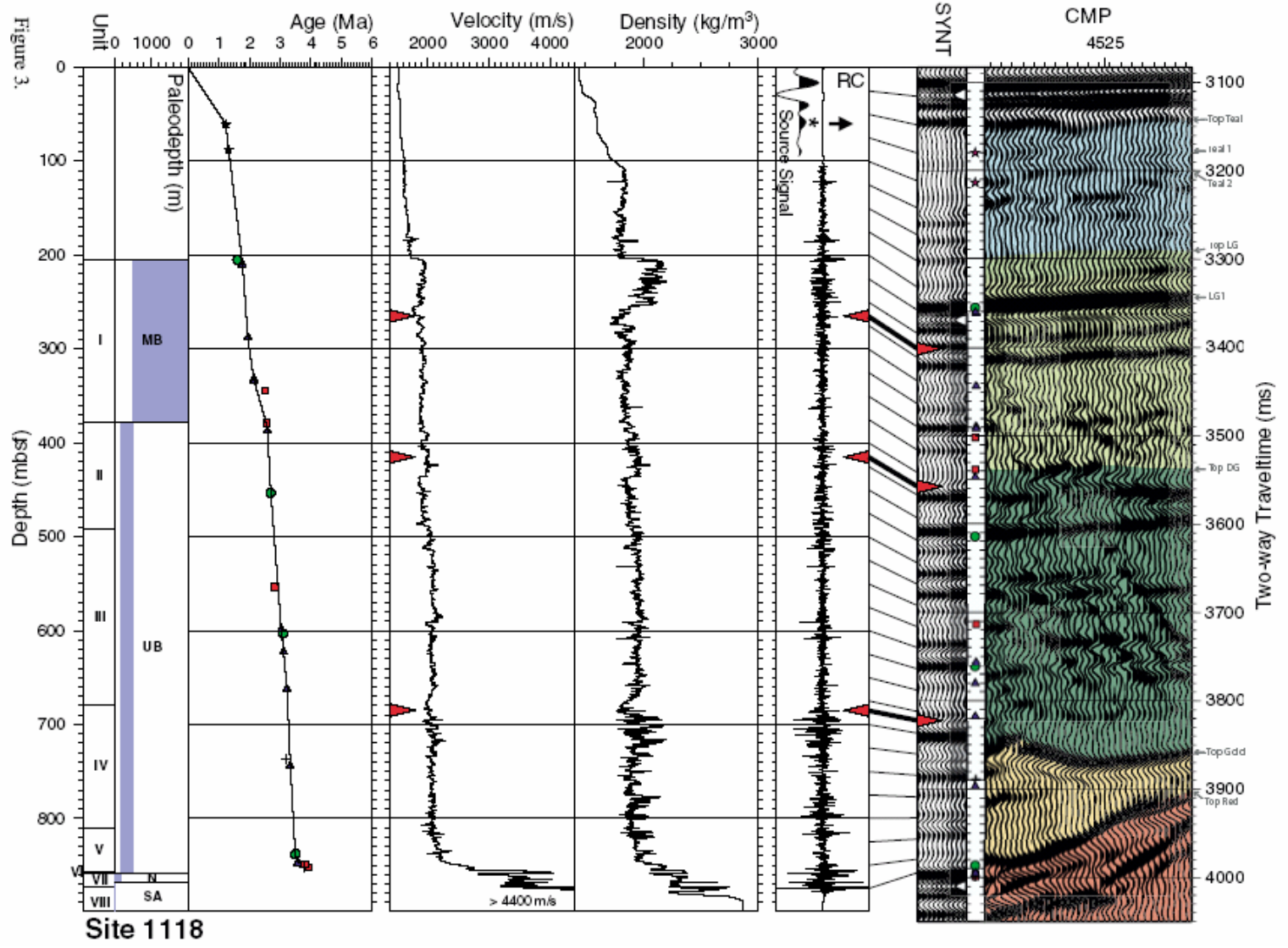
Characterization — Seismic Studies

- Seismic Reflection Data Processing
  - Seismic reflection data will be processed using ProMAX
    - Industry standard processing package produced by Haliburton
    - Standard processing steps (geometry through migration) will be completed within one month of data acquisition
    - Detailed processing will follow
      - E.g. pre-stack depth migration, amplitude variations with offset (AVO)
  - Seismic interpretation will be carried out using Kingdom Suite
    - Interpretation will include detailed attribute analysis (a Ph.D. student is being recruited who specializes in this area)
    - Interpreted (and depth converted) seismic reflection product will be a key input for reservoir simulation

Characterization — Seismic

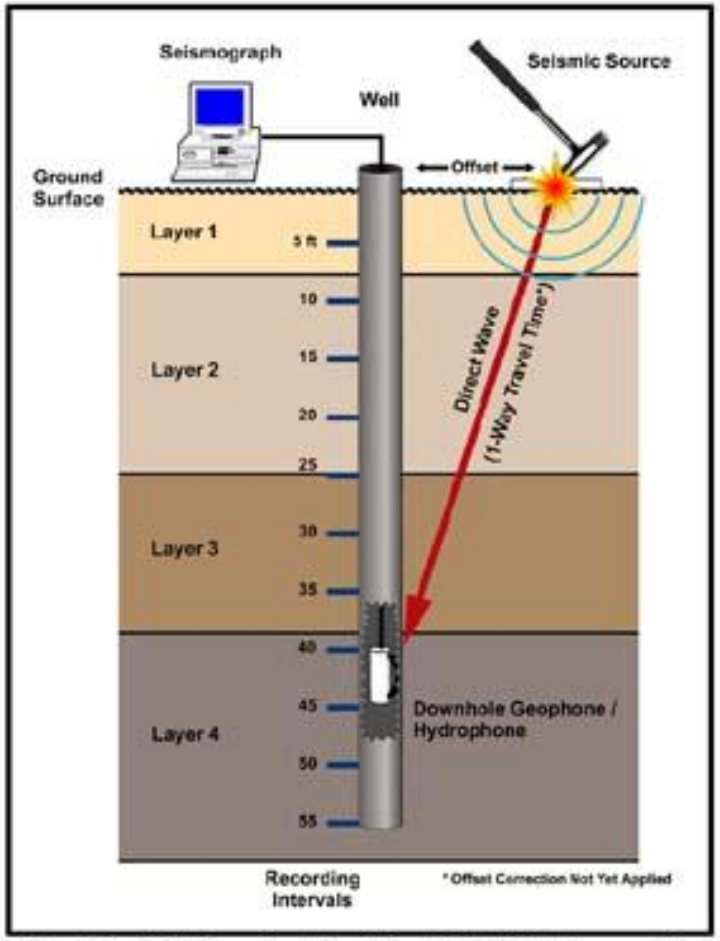
- Conventional seismic reflection data is in time
- Well data is in depth
- Ultimately we want to tie the two together and create a time-depth conversion function
  - Advanced seismic processing (i.e. pre-stack depth migration) yield a depth sections. However, this may not necessarily match the well data
  - Synthetic seismic data (derived from well velocity and density data)
    - Use downhole velocity/density data to create a reflection coefficient series that can be convolved with a known seismic signal to create a synthetic seismogram
    - Synthetic seismogram (depth) used to refine depth conversion of real seismic data (time) – example on next slide

Characterization — Seismic



Characterization — Seismic

- Another (and better) method to calibrate depth conversion of seismic reflection data – frequency content of a VSP better matches the seismic data
- Seismic source at the surface, receivers downhole
- Creates a high resolution seismic image of the area in the immediate vicinity of the borehole
- Multiple offset VSPs provide images at greater distance from wells
- Pre- and post-injection VSPs used to detect changes in the area around the well
- Cost sharing agreements with both Haliburton and Schlumberger to complete this work



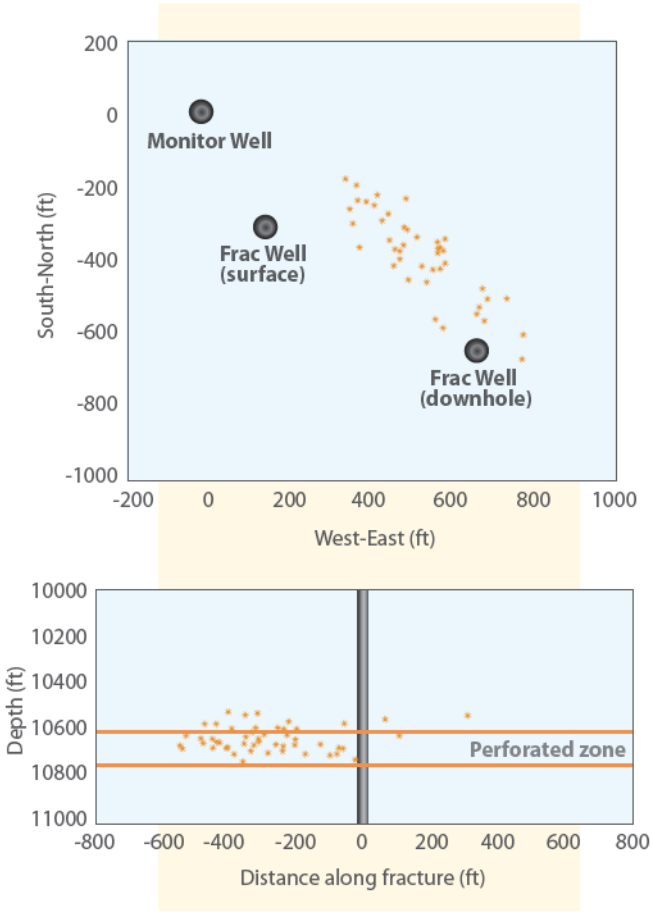
Vertical Seismic Profile (VSP) Schematic

Characterization — Seismic

- Borehole Gravity
  - Used to examine the density, porosity, and heterogeneity of rock at distances beyond the bore hole that cannot be achieved using standard geophysical logging tools
  - Measurements will be taken at 10-foot intervals in saline reservoir zones and at 40-foot intervals in select areas outside these zones.
  - Four repeat measurements at each station in the reservoir zones will maximize accuracy
  - Cost-sharing agreement in place with Micro-g LaCoste

Characterization — Seismic

- Seismic Monitoring During Injection
  - Detection of minor flow induced rock failure in the subsurface
  - Geophones cemented in shallow boreholes around the test well
  - Helps determine if injection will lead to significant seismicity and cross-formational flow during commercial sequestration operations
  - Cost-sharing agreement in place with Pinnacle (a division of Haliburton)



Characterization — Geology

- A 4000 ft well will be drilled and cored through potential injection zones and seals
- Cores will be analyzed and correlated with logging data
- Permeability and porosity will be measured
- A geologic model of the reservoir will be built
- This model will be used in reservoir simulation modeling

Characterization — Well Logging

- A cost sharing agreement with Schlumberger will allow us to run a full suite of logs
  - Triple combo
  - Lithology and continuous permeability
  - Sonic, stress anisotropy and rock strength
  - Formation structure, stratigraphy, and faulting and fractures
- In addition, cement bond logs will be run

Characterization — Injection Test

- Minifrac tests
  - Step-rate tests will be used to measure break down pressures and downhole permeability
- Injection testing
  - Large volume water injections into potential zones
  - Downhole pressure measurements during and after injection

Characterization — Mineralization

- Injected CO_2 interacts with the formation and formation fluids in complex ways
- Liquid CO_2 is less dense than the brines found in the target saltwater zones
- The standard picture of the injected fluid is a CO_2 layer floating on top of the reservoir fluids with the interactions occurring at the boundaries
- Understanding the chemistry of these interactions is important to understanding the long term storage mechanisms
- Mineralization studies undertaken as part of this project will help to understand the processes

Characterization — Mineralization

- Work will include
  - Experimental work
    - Equilibrium
    - Kinetics
    - Mass transport
    - Long term studies
  - Simulation
    - Rice University has a brine chemistry simulator that will be extended to include the data developed in the experimental work
    - Work will be initiated to include the results of these simulations into the reservoir simulator

Reservoir Simulation

- The reservoirs included in this study are not simple
- They consist of sandstone and limestone zones separated by marine shales
- A reservoir simulation model will be build using the geologic model developed in this work
- This simulator will be used to model injection and storage in the Black Warrior basin
- Simulations will be done on a coarse and fine scale
- The coarse scale simulations will be on the basin level
- Fine scale simulations will cover a more limited area

Reservoir Simulation

- **Fine-Scale Simulation will:**
  - Investigate the storage capabilities of the saline zones under a variety of injection scenarios
  - Assess geochemical interactions among rock, brine, and CO_2, including the dissolution of CO_2 in formation water.
  - Use fine grids with many components
  - Be based on fully coupled formulations
  - Relatively short time scales

Reservoir Simulation

- **Large-Scale Simulation:**
  - Will assess macroscopic CO_2-plume-migration tendencies within the basin under multiple injection scenarios.
  - Possible very long time scales
  - Probably not so many components

Best Practices Manual

- Once the study is complete we will sort through the information generated to determine which tests are the most important
- Using this, a Best Practices Manual will be developed that can be used in future projects to minimize the efforts needed to characterize a reservoir for potential carbon dioxide injection

Project Workplan/SOPO Project Tasks

- Task 1 — Project management and planning
- Task 2 — Regional Significance Studies
  - Subtask 2.1 — Geologic framework
  - Subtask 2.2 — Capacity and injectivity assessment
- Task 3 — Test Site characterization
  - Subtask 3.1 — Site design, development and characterization
    - Subtask 3.1.1 — Site selection, planning, and design
    - Subtask 3.1.2 — Conduct 2-D seismic survey
    - Subtask 3.1.3 — Well location preparation, drilling and coring
    - Subtask 3.1.4 — Well characterization completion and shut-in
  - Subtask 3.2 — Injectivity and capacity studies
  - Subtask 3.3 — Geophysical characterization
  - Subtask 3.4 — Reservoir simulation

Project Workplan/SOPO Project Tasks

- Task 4 — Containment analysis
  - Subtask 4.1 — Stratigraphic containment
  - Subtask 4.2 — Dissolution and mineralization studies
- Task 5 — Site characterization summary analysis
  - Subtask 5.1 — Site selection criteria
  - Subtask 5.2 — Risk assessment
- Task 6 — Outreach and technology transfer

Deliverables

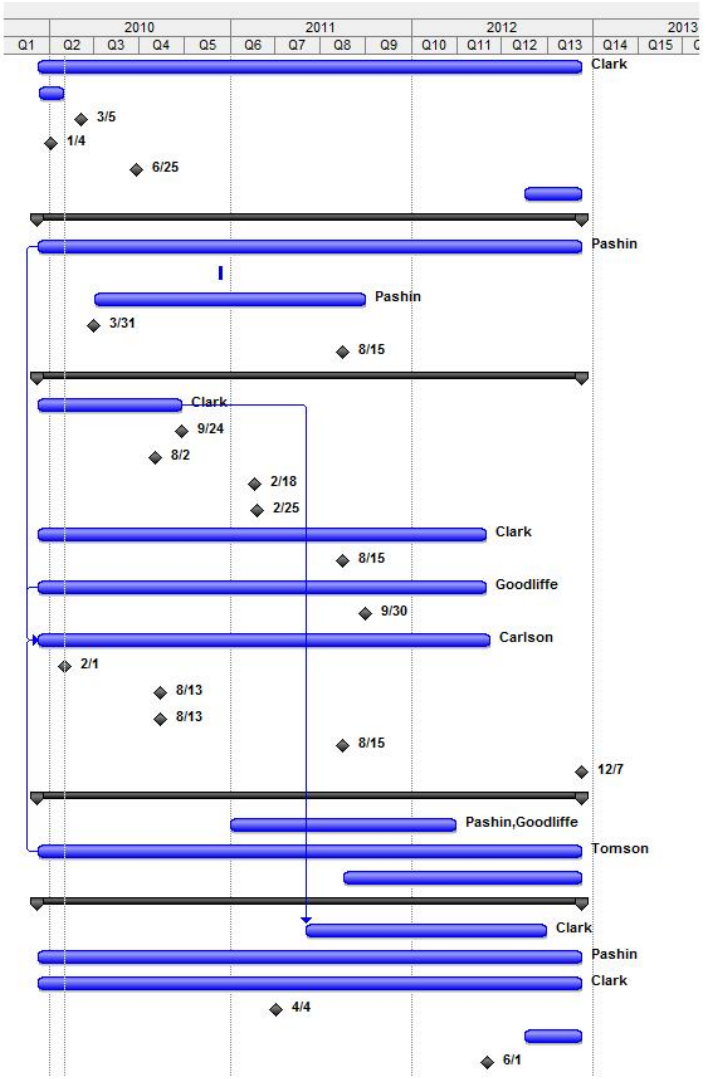
- Task 1.0 - Project Management Plan
- Task 1.0 – Project Management Plan Milestones including:
  - Submit Site Characterization Plan
  - Notification to DOE Project Manager that reservoir data collection has been initiated
  - Notification to DOE Project Manager that subcontractors have been identified for drilling/field service operations
  - Notification to DOE Project Manager that field service operations have begun at the project site
  - Notification to DOE Project Manager that activities to populate database with geologic characterization data has begun
  - Notification that characterization well has been drilled
  - Notification to DOE Project Manager that well logging has been completed
  - Notification to DOE Project Manager that activities on the lessons learned document on site characterization have been initiated

Deliverables

- Task 3.0 – Site Characterization Plan with Preliminary Well Bore Management Plan
- Task 5.0 – Best Practices Manual for Site Characterization
- Task 5.0 – Well Bore Management Plan
- Task 6.0 – Open House Highlighting Project at the Study Field Site by Approximately June 2011
- Task 6.0 – Project Website

Schedule

	WBS	Task, Subtask, or Milestone Name	Cost ($1000 DOE/Share)	Duration	Start	Finish
1	**1**	**Project Management and Planning**	200 / 50	784 days	Tue 12/8/09	Fri 12/7/12
2		*Site characterization plan*		*36 days*	*Fri 12/11/09*	*Fri 1/29/10*
3	3	Submit site caracterization plan		0 days	Fri 3/5/10	Fri 3/5/10
4		*Initiate subcontractor selection*		0 days	Mon 1/4/10	Mon 1/4/10
5	5	Subcontractor identified for drilling/field service		0 days	Fri 6/25/10	Fri 6/25/10
6		*Close test site*		*84 days*	*Tue 8/14/12*	*Fri 12/7/12*
7	**2**	**Regional Significance**		**784 days?**	**Tue 12/8/09**	**Fri 12/7/12**
8	2.1	Geologic Framework		784 days?	Tue 12/8/09	Fri 12/7/12
9		*Initiate core testing*		1 day	Fri 12/10/10	Fri 12/10/10
10	2.2	Capacity and Injectivity Asssessment		392 days?	Thu 4/1/10	Fri 9/30/11
11		*Initiate capacity estimation*		*0 days*	*Wed 3/31/10*	*Wed 3/31/10*
12		*Geological characterization completed*		*0 days*	*Mon 8/15/11*	*Mon 8/15/11*
13	**3**	**Test Site Characterization**		**784 days?**	**Tue 12/8/09**	**Fri 12/7/12**
14	3.1	Site Design and Development		209 days?	Tue 12/8/09	Fri 9/24/10
15		*Initiate site operations*		0 days	Fri 9/24/10	Fri 9/24/10
16		*Initiate reservoir data collection*		0 days	Mon 8/2/10	Mon 8/2/10
17		*Wells drilled and completed*		0 days	Fri 2/18/11	Fri 2/18/11
18	8.5	Well logging completed		0 days	Fri 2/25/11	Fri 2/25/11
19	3.2	Injectivity and Capacity		647 days?	Tue 12/8/09	Wed 5/30/12
20		*Injection and sampling complete*		0 days	Mon 8/15/11	Mon 8/15/11
21	3.3	Geophysical Characterization		647 days?	Tue 12/8/09	Wed 5/30/12
22		*Completion of geophysical testing*		0 days	Fri 9/30/11	Fri 9/30/11
23	3.4	Simulation		652 days	Tue 12/8/09	Wed 6/6/12
24		*Initiate simulation model*		*0 days*	*Mon 2/1/10*	*Mon 2/1/10*
25		*First version simulation framework*		*0 days*	*Fri 8/13/10*	*Fri 8/13/10*
26		*Coupled simulation ready*		*0 days*	*Fri 8/13/10*	*Fri 8/13/10*
27		*Revised simulation framework*		*0 days*	*Mon 8/15/11*	*Mon 8/15/11*
28		*Simulation with field data*		*0 days*	*Fri 12/7/12*	*Fri 12/7/12*
29	**4**	**Containment Analysis**		**784 days?**	**Tue 12/8/09**	**Fri 12/7/12**
30	4.1	Stratigraphic Containment		326 days?	Fri 12/31/10	Fri 3/30/12
31	4.2	Dissolution and Mineralization		784 days?	Tue 12/8/09	Fri 12/7/12
32		*Revised reactive transport models*		*345 days*	*Mon 8/15/11*	*Fri 12/7/12*
33	**5**	**Summary Analysis**		**784 days?**	**Tue 12/8/09**	**Fri 12/7/12**
34	5.1	Site Selection Criteria		348 days?	Wed 6/1/11	Fri 9/28/12
35	5.2	Risk Assessment		784 days?	Tue 12/8/09	Fri 12/7/12
36	**6**	**Technology Transfer**		784 days?	Tue 12/8/09	Fri 12/7/12
37		*Initiate database entry*		0 days	Mon 4/4/11	Mon 4/4/11
38		*Simulation framework available to public*		*84 days*	*Tue 8/14/12*	*Fri 12/7/12*
39	14	Initiate lessons learned document		0 days	Fri 6/1/12	Fri 6/1/12



Milestones

ID	Milestone	Planned Completion Date	Actual Completion Date	Validation
4	FOA Milestone: Updated Project Management Plan	03/05/10		
5	HQ Milestone: Kick-off Meeting Held	03/31/10	02/03/10	
6	FOA Milestone: Submit Site Characterization Plan	03/05/10		
7	HQ Milestone: Semi-Annual Progress Report on data availability and field contractors	09/30/10		
8	HQ Milestone: Annual Review Meeting attended	03/31/11		
9	HQ Milestone: Annual Review Meeting attended	03/30/12		
12	FOA Milestone: Notification to Project Manager that reservoir data collection has been initiated	08/02/10		
13	HQ Milestone: Begin collection of formation information from geologic surveys and private vendors	06/30/10		
18	FOA Milestone: Notification to Project Manager that subcontractors have been identified for drilling/field service operations	06/25/10		
19	FOA Milestone: Notification to Project Manager that field service operations have begun at the project site	09/24/10		
20	FOA Milestone: Notification to Project Manager that characterization wells have been drilled	02/18/11		
21	FOA Milestone: Notification to Project Manager that well logging has been completed	02/25/11		
25	HQ Milestone: Establish database links to NATCARB and Regional Partnerships	12/31/10		
26	FOA Milestone: Notification to Project Manager that activities to populate database with geologic characterization data has begun	04/04/11		
27	FOA Milestone: Notification to Project Manager that actvities on the lessons learned document on site characterization have been initiated	06/01/12		

Project Status

- Subcontracts with Rice University and the Geological Survey of Alabama have been sent out
- Three students in Chemical Engineering and one in Geology have joined the project. In addition, an offer has been extended to another student.
- Background data gathering has commenced.
- The Gorgas site has been visited and a drilling site selected.

Drilling Site

Drilling Site

GPS 33.6499167- 87.196472

Project Summary

- Goals
  - Determine the CO_2 storage capacity of multiple stacked saline formations in the Mississippian-Pennsylvanian section of the Warrior Basin of Alabama
  - Assess the risks associated with geologic carbon storage in these sections of the Black Warrior basin
  - Develop a regional plan for carbon sequestration
- Performance Period
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- Budget Summary
  - Total project cost — $6,538,621
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- Students have been added to the project
- Initial data collection has commenced
- A drilling site has been selected